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ABSTRACT

On the premise that many laboratory instructors lack knowledge about chemical toxicity, this study investigated three areas: (1) chemicals used in the academic laboratory which pose a health hazard; (2) ways of reducing toxicity in the laboratory (with attention to the apparent lack of teacher training which contributes to the cause of the problem and to suggestions for monitoring units and facility devices to reduce the hazard); and (3) state and federal regulations and resource materials for the proper handling and disposal of hazardous chemicals. An annotated bibliography is included which examines each of these areas. Findings clearly establish the need for teachers to be informed of the chemicals which are potential health hazards and indicate that educating laboratory instructors to the hazards of certain chemicals is the initial approach to reducing the dangers of chronic poisons in the classrooms. Recommendations based on these and other findings include removing all carcinogenic chemicals from classroom and storage areas, formulating and using a predetermined waste disposal program before an experiment is performed, and having all laboratory instructors participate in a formal health safety program. (JN)

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AN ANNOTATED BIBLIOGRAPHY OF THE LITERATURE DEALING WITH THE HAZARDOUS CHEMICALS USED IN THE CHEMISTRY LABORATORY

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Submitted in partial fulfillment of the requirements
for the course S591--Exit Project
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INTRODUCTION

Cancer! It seems everything can produce it--from the food we eat to the air we breathe. The cause and effects of cancer on humans has gained national attention in recent years. The federal government now regulates the amount of chemicals that can be released to the environment, added to food and exposed to workers.

Carcinogens, or cancer causing substances, have been related to occupational hazards since 1776 with Percivall Pott's study between carbon soot and scrotal cancer among chimney sweepers (Labiance). The use of benzene was reduced in Goodyear tire manufacturing plants during the 1940's when Peter Infante's found it to be linked to leukemia (L. Carter). The government has been forced to be concerned for the health and safety of industrial workers. Since the earlier seventies, the Occupational Safety and Health Administration (OSHA) has mandated industries to comply to the standards set for hazardous chemical exposure.

The American school system has failed to observe these OSHA regulations and has ignored educating the teachers to potentially dangerous chemicals. Many of the bodily effects caused by carcinogens will not be observed for many years to come. Therefore, the science educators

should provide the respect of chemical safety to their students in order to provide a healthier generation.

STATEMENT of the PROBLEM

The laboratory instructor may be unknowingly exposing students and our environment to chemicals which are a potential health hazard (Newell). Society holds a teacher legally liable for the health and safety of their students (Nagel). It is imperative that our educators be informed to the chemicals which are toxic and carcinogenic, reduce the hazard and dispose of the hazard in an environmentally safe manner.

PURPOSE of the STUDY

In the last fifteen years, governmental attention has increasingly been directed towards the bodily effects chemicals have on humans. This is evident by the many regulations now in effect for the exposure limits of toxic chemicals. The chemistry teacher, therefore, is being forced to develop a safer place for learning, yet, they lack the necessary training to handle hazardous chemicals (Brubaker). An instructor must be educated to the proper dispensing, disposal and reduction of hazardous chemicals to ensure health safety in the classroom.

ORGANIZATION of the STUDY

In order to inform the chemical laboratory instructor on the health safety of certain chemicals, it would be necessary to ask three important questions: (1) What chemicals used in the academic laboratory propose a health hazard? (2) How can the hazard of toxicity be reduced in the laboratory? and (3) What are the proper legal procedures?

The introductory portion of this paper has already established a lack of knowledge among lab instructors for chemical toxicity. The first question will require a comparison of the tables found in the appendix and investigate the validity to the limits of exposure. The second question will address the apparent lack of teacher training which contributes to the cause, and then suggest monitoring units and facility devices to reduce the hazard. The final question will look at federal and state regulations along with several resource materials for the proper handling and disposal of hazardous chemicals.

LIMITATION of the STUDY

There was a suitable amount of opinionated literature by accredited people on the proper handling and disposal of hazardous waste. However, the limits of exposure to chemicals were based on industrial personnel. In no way

are academic students exposed to the quantity or for the same length of time as industrial workers are to toxic chemicals. It can then be assumed the degree of severity is lessened in the classroom; however, it should still be treated as a hazardous situation whenever toxic chemicals are used. Finally, no research data was available due to the relatively new and constantly changing subject of the proper handling of chemical toxicity.

GLOSSARY

acute--having a rapid onset, severe symptoms, and a relatively short duration; not chronic. (Considine 1976:34)

bioassay--determination of the relative strength of a substance (as a drug) by comparing its effect on a test organism with that of a standard preparation. (Webster 1974:110)

carcinogen--a substance capable of causing cancer or cancerous growth in mammals. "Known" labels indicate that sufficient information exists which shows a definite relationship between exposure to a substance and cancer in humans. "Probable" labels indicate there is limited evidence in humans and/or sufficient evidence in experimental animals. (Council of State Science Supervisors (CSSS) 1984:7)

chronic--of long duration, applied to a disease that is not acute. (Considine 1976:547)

corrosive--a substance that causes destruction of tissue by chemical action on contact. (CSSS 1984:7)

epidemiology--the study of the relationships of the various factors determining the frequency and distribution of diseases in a human community. (Friel 1981:451)

explosive--an unstable substance capable of rapid and violent energy release. (CSSS 1984:7)

hazardous--the probability that injury will result from a particular way of using a material. (Steere 1971:7)

inhibitor--any substance that interferes with a chemical reaction, growth or other biological activity. (Friel 1981:667)

irritant--a substance that on immediate, prolonged, or repeated contact with normal tissue will induce a local inflammatory reaction. (CSSS 1984:7)

mutagen--a substance capable of causing changes in the genetic material of a cell, which can be transmitted during cell division. (CSSS 1984:7)

teratogen--an agent or factor that causes the production of physical defects in the developing embryo. (Friel 1981:1317)

threshold--that value at which a stimulus just produces a sensation, is just appreciable, or comes just within the limits of perception. (Friel 1981:1364)

toxic--agents or substances that when inhaled, absorbed, or ingested in small amounts can cause death, disablement, or severe illness. (CSSS 1984:7)

volatile--tending to evaporate rapidly. (Friel 1981:1463)

ANNOTATIONS

WHAT CHEMICALS ARE HAZARDOUS?

Newell, R.C., "Danger Behind the School Door", American Educator, v3, n2, Summer, 1979, p. 8-11.

In many schools across the nation, teachers and students alike are exposed to a number of hazardous agents from various chemicals used in the classroom. Specifically, the chemicals include asbestos, cadmium and lead, benzene and carbon tetrachloride. Lead when ingested has been linked to kidney disease, anemia, central nervous system damage, sterility and birth defects. Cadmium and carbon tetrachloride along with other common metals have damaged the central nervous system, respiratory ststem, the liver and the kidneys. In 1978, the U.S. Consumer Product Safety Commission voted to ban benzene except for in laboratory use. Benzene has been linked to the formation of leukemia. For removal of benzene from the high school labs, the local school board will have to approve the removal.

Nagel, Miriam C., "How Much Is Too Much? Toxic Chemicals in High School Lab", Journal of Chemical Education, v59, n12, December, 1982, p. 1040-1041.

In response to an article found in the Good Housekeeping (April, 1978) and based on information from the Consumer Product Safety Commission, Nagel claims the article has unnecessarily drawn the attention of high school chemistry students' parents to dangers that do not exist in the lab. The CPSC could benefit more by supplying teachers with their results or information instead of to a popular magazine. It is the teacher's moral and legal obligation to provide a safe atmosphere for their students. In order to do this, one must weigh the risk and the benefits when using hazardous chemicals in a 90 minute lab period. Toxic chemicals enter the body by inhalation, skin absorption, eye contact and ingestion, all of which can be controlled with the proper safety procedures. Several references are cited to give a chemistry teacher access to safety programs. One book of great value is "Pocket Guide to Chemical Hazards".

Miriam Nagel is a chemistry teacher at Avon High School, Avon, Connecticut.

Lewis, Richard J. and Sweet, Doris V. ed., "Registry of Toxic Effects of Chemical Substance", U.S. Department of Health and Human Services, National Institute of Occupational Safety and Health, DHHS (NICSH), Pub. No. 83-107-4, Cincinnati, Ohio, April, 1984, (Microfiche).

These agencies periodically review the hazardous chemicals which have toxic effects on the human body. To date, more than 100,000 chemicals have been investigated. In this report, a list of chemical names are given acceptable limits of exposure and bodily effects as a resource to provide health safety for laboratory personnel in contact with these substances.

Refer to Table 1 in appendix.

Gori, Gio Batta, "The Regulation of Carcinogenic Hazards", Science, v208, n18, April, 1980, p. 256-261.

In the United States, the need for regulation of carcinogens was introduced as social dialectic. The laws do not consider the risk benefits, but contests that health should be valued at all costs. Ambiquity exists today in the regulations due largely to the U.S. legislators still referring to the initial standards of exposure from the 1950's, when very little information existed. The discussion of regulations of carcinogens relies on animal testing. This can be steered in the direction of the experimenter's intent. Therefore, bias results of bioassays can point to positive responses. The current regulatory processes must be changed to include standards of usefulness and a standard of safety or tolerance. Substances with particular uses can then be regulated accordingly.

The author is Deputy Director, Division of Cancer Cause and Prevention, National Cancer Institute, Bethesda, Maryland.

Labianca, Dominick A., "The Chimney Sweepers' Cancer: An Interdisciplinary View of Chemical Carcinogenesis", Journal of Chemical Education, v59, n10, October, 1982, p. 843-846.

Chemistry is linked to fields of study such as literature and social studies through the effects chemicals have on humans.

The Chimney Sweepers' Cancer does just that. With Percivall Pott's study of scrotal cancer among chimney sweepers in 1775, the birth of carcinogenesis was proclaimed. A community concern for the health of workers inspires the scientific research between the chemicals found in the work area and the health of the workers. This can be expanded to today's examples of exposure to various chemicals.

Carter, Luther J., "Dispute Over Cancer Risk Quantification", Science, v2-3, n30, March, 1979, p. 1324-1325.

It seems the Occupational Safety and Health Administration (OSHA) and the Environmental Protection Agency cannot see "eye-to-eye" on the regulations for exposure limits of the carcinogen benzene. One difference is the EPA is an environmental agency where OSHA is concerned for the health of industrial workers. The study conducted by Peter Infante in 1940-1949 at two Goodyear plants in Ohio, showed out of 748 workers tested, 9 deaths were related to leukemia. These workers were exposed to 100 ppm or more of benzene during an eight hour day. This study plus epidemiological studies done in the 1970's shows a link between benzene and leukemia. Because of these studies, OSHA has recommended the courts to enforce a 1 ppm exposure limit. Benzene is used mostly in chemical, petroleum and tire manufacturing industries, and it would cost these industries about $500 million to reduce the exposure to OSHA's suggested limit. The Fifth Circuit Court of Appeals ruled in favor of the industries and told OSHA to present more facts on the quantities of benzene that a person can be exposed. The Secretary of Labor stated it would be impossible to obtain with any precision, the number of cases of cancer caused by benzene exposure alone because of the many variable substances people are exposed.

Smith, Roger M., "Benzene, A Familiar Hazard?", Journal of Chemical Education, v57, n3, March, 1980, p. A85-86.

Benzene has been recognized as a toxin for over 75 years. Yet laboratory manuals still call for its use without stating the precautions necessary for handling it. Most manuals cite its flammability but not its toxicity by demanding the procedure be carried out in a hood. According to OSHA in 1971, a limit of exposure over an eight hour day was 10 ppm of benzene. Later by 1980, the limit was reduced to 1 ppm or 5 ppm per 15 minutes. Benzene which can enter the body by inhaling or by absorption through the skin, was found to be linked with leukemia. In the U.S.A., no restrictions are put on the use of benzene in the educational laboratories. In 1973, the United Kingdom teachers were warned that benzene is a chronic poison, and along with asbestos wool, it should not be used in the school laboratories.

The author holds an honor degree in chemistry, a Ph.D. degree in chemistry and is involved in research in chemotonomy.

Carter, D.E. and Fernando, Quintus, "Chemical Toxicology", Journal of Chemical Education, v56, n8, August, 1979, p. 490-495.

Not all toxic chemicals are organic solvents. Beryllium, cadmium, lead and mercury, as well as their compounds, are metals considered to be a severe industrial hazard. Cadmium used in the manufacturing of batteries is considered a chronic poison in that it has caused crippling and even death. Cigarette smoke contains 1.1 ug of cadmium. Once lead enters the body, it accumulates in the bones and effects the nervous system. Exposure to elemental mercury effects the central nervous system and causes emotional disturbances. Many chemistry laboratories, including academic labs, exceed the limit of mercury exposure, 0.005 mg/m. Metal toxicity is caused by the metal entering the body by inhalation, skin absorption, or ingestion of its compounds.

Carter is an Associate Professor of Toxicology and Fernando is a Professor of Chemistry, both are at the University of Arizona.

Council of State Science Supervisors. School Science Laboratories: A Guide to some Hazardous Substances, Washington, D.C.: U.S. Consumer Product Safety Commission, and National Institute for Occupational Safety and Health, 1984.

A set of guidelines provides an aid to a science teacher in the proper handling and storage of hazardous chemicals. Included in this booklet are several lists of chemicals classified as explosive, human carcinogens (suspected and known), animal carcinogens or mutagens, highly toxic and corrosive or irritating. To house these chemicals, a suggested method of shelf storage is given along with an inventory list of hazardous storage for chemicals found in the school laboratory.

HOW CAN THE HAZARD BE REDUCED?
TEACHER TRAINING

Chemical and Engineering News, "Toxic Chemicals Use in School Labs Examined", v60, n5, February 1, 1982, p. 5-6.

States the result of a survey of twenty-two schools for the number of accidents occurring in the laboratory and the number of schools ordering hazardous chemicals. Most accidents in the lab were chemical burns and lacerations due to broken glass. As many as thirty-three chemicals ordered each year by high school chemistry teachers are listed as suspected or known carcinogens. Instructors lack the available information on the potential chronic health effects from these chemicals. As a result, the Consumer Product Safety Commission is reviewing the use of chemicals used in the secondary school laboratory and will most likely begin providing educational materials on this matter.

Brubaker, Inara M., Finkbeiner, Herman L., and O'Neil, George J., "Laboratory Safety Is Everyone's Responsibility", Chemical and Engineering News, v59, n30, July 27, 1981, p. 92.

The authors give a summary of a survey conducted by the Task Force on Occupational Health and Safety and assisted by the American Chemical Society. The purpose of the survey was in respondence to OSHA policy on laboratory employee protection from exposure to chemicals. The survey has shown a fair appreciation for lab safety and health of lab workers. However, more than fifty percent of academic labs do not have safety training programs and twenty-two percent have no predetermined waste disposal policy. The instruction for chemical safety and safety awareness must be provided by the chemistry teacher. A separate toxic chemical policy for academic laboratories should be provided instead of the present industrial policy.

Inara Brubaker is the chairman of Task Force on Occupational Health and Safety; Herman Finkbeiner is the chairman of Committee on Chemistry and Public Affairs and George O'Neill is chairman of the Committee on Chemical Safety.

Chemical and Engineering News, "Strategies for Improving Safety Developing", v59, n15, April 13, 1981, p. 56-68.

Chemical educators are forced to develop clever new approaches for making the learning center a safer place. The big dilemma for educators is the strict safety standards that are forcing them to modernize their facilities, yet no funds are available to implement the standards. Some educators believe that formal safety courses will be mandatory in the near future. Due to the overcrowding of the chemistry curriculum now, this new required course will be heavily criticized. Safety should be taught to the instructor for legal protection. Good safety procedures and detailed safety instructions should be in writing before each lab is performed. Teaching safety can help protect a teacher and administration in a legal suit. Robert Parry, President of the American Chemical Society, stated, "Those in teaching need a definitive document stating the implementations for safety practice."

Nicholls, L. Jewel, "An Undergraduate Chemical Laboratory Safety Course", Journal of Chemical Education, v59, n10, October, 1982, p. A308-304.

Describes the safety course in the chemistry department offered at the University of Illinois at Chicago Circle. The course not only covers the usual safety procedures like the use of goggles, eye wash, fire extinguishers and blankets, but emphasizes the toxicity, storage and disposal of chemicals. The students are required to do problem solving and perform calculations for practical laboratory safety situations. The students make extrapolations and judge the validity and applicability of toxicity and epidemiology data. The final exam involves the evaluation of hypothetical unsafe laboratory situations.

L. Jewel Nicholls holds a B.S. and Ph.D. in chemistry and is currently the Coordinator of the Undergraduate Laboratories and Storerooms at UICC.

ATMOSPHERIC MONITORING

Mohrig, Jerry R., "Learning How to Run Safer Undergraduate Laboratories", Journal of Chemical Education, v60, n10, October, 1983, p. A355-360.

Laboratory safety should be taught at the undergraduate level and be part of the curriculum. A teacher must first learn about safety by referring to several books on laboratory safety so he has a list of chemicals which are carcinogenic. How does one know if an experiment is a health danger? By monitoring the atmosphere is the only sure way to answer this question, also by referring to the Threshold Limit Values (TLV) will give clues to potential dangers. Mohrig did a presentation on safety to his organic students and to his surprise, the students showed a respect for the chemicals and even developed a good housekeeping mannerism. Chemical disposal can be avoided by recycling and reusing recovered hazardous chemicals for use later.

Jerry Mohrig is a Professor of Organic Chemistry at Carleton College in Northfield, Minnesota.

Freifeld, Milton, "What's In the Air? How Much Is Too Much? Measurement of Toxic Gases, Vapors, and Particular Limits of Exposure", Journal of Chemical Education, v59, n11, November, 1982, p. A351-354.

Discusses the methods of monitoring the organic vapors in the laboratory. Reviews criteria for safe levels of airborne contaminates or toxic gases which are inhaled. The National Academy of Science suggests when an organic substance is used three or more times a week or large quantities of the substance are stored in the lab, monitoring of the air should be done. Several personal samplers or monitoring units are suggested for use, depending on the area needed to be sampled. These units will produce data according to the Time Weighted Average (TWA) which is an eight hour day or forty hour week for industrial workers.

The author is an Associate Director of Health, Safety and Chemical Regulations at the Chemical Manufacturers Association.

Pierce, J.T., McDonald, S.M., and Scogin, M.S., "Experiments Integrating Evaluation of Chemical Hazards Into the Chemistry Curriculum", Journal of Chemical Education, V61, n3, March, 1984, p. A83-85.

At the University of North Alabama, senior students monitored the air in the laboratory with the use of a gas chromatography. Two experiments were performed: sampling of hydrogen sulfide (H_2S) gas during qualitative analysis and sampling of organic solvents during an organic lab exercise. Both experiments used no hoods when sampling. Using the National Institute for Occupational Safety and Health (NIOSH) manual for sampling and analysis, the results showed overexposure to H_2S gas during the generation of the gas for qualitative analysis; 246 mg/m^3 found, 21 mg/m^3 is accepted. If a hood was used, the limits of exposure would be in the acceptable range. The results for the organic vapors showed no overexposure during the organic labs.

J.T. Pierce is an Associate Professor of Industrial Hygiene at U of N.A. and S.M. McDonald and M.S. Scogin are senior industrial hygiene students.

Bayer, Richard, "Toxic Vapors and Ventilation Parameters", Journal of Chemical Education, v59, n12, December, 1982, p. A385-389.

Working with chemicals at "acceptable risk" to workers could be accomplished with the use of proper ventilation. The levels of toxic chemicals in the laboratory atmosphere depends on the rate they are introduced and the rate at which they are removed. An instructor can monitor the levels of toxic vapors in his/her lab by using Patty's Industrial Hygiene and Toxicology standard reference. This method has been revised by Bayer for the academic laboratories.

Richard Bayer is Professor of Chemistry at Carrol College and president of an independent laboratory, Bionomic Corporation, which is concerned with solving problems in chemistry and biology.

Chemical and Engineering News, "HEW to Set Laboratory Safety Standards", v56, n41, October, 1978, p. 9.

The Department of Health, Education and Welfare has begun to set guidelines for developing safeguards to protect laboratory personnel from exposure to biological, chemical and physical carcinogens. Along with the guidelines, HEW will provide work practices and engineering controls for dealing with carcinogens. The guidelines are given in detail for the proper techniques to be used by workers handling carcinogens. New laboratory devices and apparatus must be installed along with adequate ventilation. Periodical medical examinations of all personnel handling the carcinogens will also be mandatory.

WHAT ARE HANDLING and DISPOSAL PROCEDURES?

Joyce, Robert M., "Prudent Practices for Disposal of Chemicals from Laboratories", Science, v224, n4648, May 4, 1984, p. 449-452.

All laboratories must dispose of chemical waste in a safe manner that is environmentally acceptable and that conforms to federal, state and local regulations. According to the National Research Council's (NRC) definition of a laboratory, all academic labs are included. Transportation of waste must be approved by the Department of Transportation and the Environmental Protection Agency (EPA). Solutions to help reduce waste disposal problems are: (1) reduce the volume of waste by recycling; (2) have a waste disposal program designed; (3) segregate waste according to classification and (4) disposal of waste according to EPA regulations.

Robert Joyce is formerly a research director at E.I. DuPont de Nemours & Company, Wilmington, Delaware. He also assisted in the preparation of the National Research Council report.

Allen, Ralph O., "Waste Disposal in the Laboratory: Teaching Responsibility and Safety", Journal of Chemical Education, March, 1983, v60, n3, p. A81-85.

The EPA defines hazardous waste as material which is ignitable, corrosive, reactive or toxic. This includes almost all the chemicals used in the high school laboratory. Allen informs instructors that they are considered by the EPA as hazardous waste generators. Chemistry teachers must comply to the EPA regulations for the proper and safe disposal of chemical waste or face prosecution. The author gives the reader alternatives to generating less waste and maximizing the collection of waste. He also provides a detailed procedure for the disposal of hazardous waste according to the EPA regulations. Two alternatives given: (1) hire a commercial disposal firm and (2) do the work yourself by reclamation, volume reduction and neutralization of waste. Allen gives the reader the specific procedures to carry out both alternatives. He warns the instructor to check disposal firms for an EPA permit and that instructors must be licensed by the EPA in order to bury chemicals in the ground or pour them down the drain.

Ralph Allen is an Associate Professor of Chemistry and the Director of the Office of Environmental Health and Safety at the University of Virginia.

Young, Jay A., "Academic Laboratory Waste Disposal: Yes, You Can Get Rid of That Stuff Legally!", Journal of Chemical Education, June, 1983, v60, n6, p. 490-492.

The author's purpose is to notify teachers of high schools and small colleges the legal procedures available for the disposal of chemical wastes. The simplest procedure is to pay the Environmental Protection Agency (EPA) to take the waste away; however, this is very costly. The second alternative is time consuming for the instructor who must separate and label all waste as nonhazardous or hazardous which has an additional four categories. The school must purchase EPA containers and then hire this agency to dispose of the waste all at a lower fee. Young warns instructors that it is illegal to dump waste materials in the ground without a license. The final alternative lies within the classroom. The instructor should reduce the volume of product chemicals used in a procedure, recycle hazardous waste, and order substitute chemicals to reduce the hazard. Several tables are provided, listing the hazardous chemicals. Young notes the EPA considers solvents as hazardous solids.

Jay Young is a chemical consultant specializing in the safe manufacture, use, precautionary labeling, proper handling, and appropriate disposal of chemicals used in the laboratory.

Rothchild, Robert, "1,1-Trichloroethane", Journal of Chemical Education, v60, n9, September, 1983, p. A228.

Substituting a less hazardous chemical for a more dangerous one has developed some unwanted reactions with the inhibitors or additives (used to cut down on oxidation) found in the substitute chemical. There seems to be no problem with substituting toluene for benzene. The problem was found when using 1,1-trichloroethane for carbon tetrachloride. The inhibitor dioxane, which by the way is a know carcinogen, forms crystals in various organic reactions. In order to provide safety, the chemist must deal with unwanted reactions.

Robert Rothchild holds a B.S., M.A., P.Phil, and Ph.D in chemistry.

Burns Indiana Statutes. Title 13, Article 7, 1980

Chapter 4: Prohibits the dumping and delivery of any hazardous waste to a facility which is not an approved dumping site.

Chapter 7: Anyone can apply to the board for a disposal license, provided a petition of 200 names is accompanied with the application.

Chapter 13: Violators of this article shall be penalized $25,000 per day of the violation as a maximum fine and indirect violators will be fined up to $500 per day of offense.

Chemical and Engineering News, "Schools Remove Hazardous Chemicals from Labs", v60, n39, September 27, 1982, p. 27.

The New York section of the American Chemical Society had set up a survey team of academic chemists to inspect state colleges' chemistry laboratories for possible hazards. Of the 21 colleges inspected at this writing, it was found that the hazardous problems are confined mostly to the storage areas. Most store rooms do not segregate reactive chemicals, instead, they are stored alphabetically. Most storage rooms have inadequate ventilation and storage for volatile chemicals. Too many unlabeled bottles and waste solvent containers are in the storage area. Shelving is too high or beginning to rust. Floor areas are cluttered and bottles are piled. It's the instructors' responsibility for safety to prevail in the storage room. Iowa has a program to provide instructors with guidelines for the safe storage of hazardous chemicals. Iowa's Public Instruction, the EPA, Department of Environmental Quality and fire marshalls are working with the state Department of Education and local schools to remove dangerous chemicals from the classrooms.

Pennsylvania Department of Education. Guide for Science Laboratory Safety, 1981, Harrisburg, PA.

The booklet contains valuable information for all personnel connected with a science laboratory. Included in this publication are safety procedures for the use of chemicals, radiation, laboratory animals, micro-organisms, plant, lasers, electricity, and model rockets. In the chemical section, the proper procedure for chemical storage, disposal, toxicity of chemicals, and a list of incompatible chemicals (those chemicals which form violent reactions with one another) are given. Also included are rules and regulations for handling radioactive substances, from the United States Nuclear Regulatory Commission.

Gallagher, Barbara, "The ACS Chemical Health and Safety Referral Service", Journal of Chemical Education, v61, n7, July, 1984, p. 650-651.

The American Chemical Society provides referrals to literature, films, educational courses and organizations that can provide answers to questions concerning the health and safety of individuals involved in handling chemicals. The most common questions asked by industrial, governmental employees, academic, and independent people are how to dispose of unwanted chemicals and is a specific chemical toxic or hazardous. These questions and others are answered by professionals or referrals are given to other resources. To get in touch with this organization, dial (202)872-4511 or wirte: American Chemical Society
1155 Sixteenth Street, N.W.
Washington, D.C. 20036

Baker, Charles, J., The Firefighter's Handbook of Hazardous Materials, 2nd ed., 1973.

This pocket size handbook provides data to determine the relative toxicity, flammability, thermal stability, permissible extinguishing agents, and other pertinent information of a given substance.

Steere, Norman V., ed. CRC Handbook of Laboratory Safety, 2nd ed. Boca Raton, Florida, CRC Press, Inc., 1983.

This handbook provides convenient information for hazard recognition and control. Special emphasis is placed on organization of a laboratory safety program. Principles and Procedures for Evaluating Toxicity of Chemicals, Mode of Action of Toxic Substances, Disposal of Hazardous Waste, and Radiation and Biological Hazards are topics used in aiding the development of a safety program.

Johnson, James S., "Carcinogen Control in the Chemical Laboratory", Journal of Chemical Education, v58, n9, September, 1981, p. A257-262.

Johnson developed a detailed chemical safety program to classify and control carcinogens and toxic chemicals used in the chemistry lab. The article includes a detailed description of his program. He provides in an outline form, guidelines in the purchasing and receiving of toxic chemicals, practices to be conducted in the laboratories, and special personal safety requirements for the handling of carcinogens. Of some value, Johnson provides an example log sheet used to inventory hazardous chemicals stored in a lab. The controls on chemicals he provided were directed to industrial labs but can easily be applied to academic laboratories.

The author holds a M.S.H. degree in Air Pollution and Industrial Hygiene and a Ph.D. in Inorganic Chemistry. Presently, he is a field industrial hygienist at Lawrence Livermore National Laboratory.

Walters, Douglas B., Safe Handling of Chemical Carcinogens, Mutagens, Teratogens and Highly Toxic Substances, v1, Ann Arbor, Michigan: Ann Arbor Science Publishers, 1980.

The emphasis of this book is on the control and use of hazardous chemicals found in a research laboratory. Section I focus is on the laboratory facilities, the safe handling procedures, management of hazardous materials, and implementing a safety program. Section II notes the necessity of monitoring chemicals in the laboratory atmosphere so as to provide a medical surveillance on the employees. Finally, Section III classifies chemicals according to their toxic effects and their industiral use. Walters uses the Lawrence Livermore Laboratory's Chemical Carcinogen Control Program (p. 142-152) as a safety guide for handling carcinogens. Included are special requirements for the safe storage and handling of presumptive carcinogens and known carcinogens. A detailed log sheet provides an inventory.

SUMMARY

Newell expressed concern for the number of hazardous chemicals used in the classroom, exposing students and teachers to potential health dangers. But Nagel believes this has drawn unnecessary attention among parents because the dangers are present in an industrial laboratory and not in a short ninety minute exercise as in a high school chemistry course. He believes the benefits will outweigh the risks but notes it is the teacher's legal and moral obligation to provide a safe atmosphere for learning. Therefore, a teacher needs to know what chemicals propose a potential health hazard.

Toxic chemicals can enter the body by inhalation, skin absorption, eye contact and ingestion, all of which can be controlled with proper safety techniques. Chronic chemicals most often cause cancer in the body and are labeled carcinogenic. The National Institute of Occupational Safety and Health (NIOSH) has a current list of chemicals and their toxic effects (refer to Table 1). Lewis and Sweet (10) admits that "there is no qualifying limitation on the duration of exposure or for the quantity or concentration of the substance, nor is there a qualifying limitation on the circumstances that result in the exposure." Gori believes that ambiquity exists today in the standards of carcinogenic exposure largely due to the bias results of animal bioassays

which can be easily steered in the direction of the experimenter's intent.

Knowledge of carcinogens was first brought to the public's attention back in 1775 as Labianca cites the results of Percivall Pott's study of scrotal cancer among chimney sweepers. L. Carter also emphasizes the importance of Peter Infante's survey during the 1940's as evidence for a linkage between benzene and leukemia.

Looking at a few selected laboratory manuals used in high school chemistry courses, benzene is required by more than half the authors for some experimental procedures. L. Carter also quoted the Fifth Circuit Court of Appeals ruling not to ban benzene from the industrial market until more substantial data is provided by NIOSH. Yet, Smith reveals benzene has not been recommended for academic use in the United Kingdom since 1973.

Benzene is not the only toxic chemical found in the science laboratory. NIOSH considers the chemicals found in Table 2 to be severely to less severely toxic because of the varying exposure limits. It should be noted that chemicals which are taken for granted, like acetone and methanol, do have potential toxic effects.

The U.S. Consumer Product Safety Commission (CPSC) strongly urges schools to remove the carcinogens, probabe

carcinogens, and explosives listed in Table 3. The substances identified as animal carcinogens and mutagens should be handled with extreme caution. A comparison of Tables 2 and 3 shows publishers are requiring instructors to order chemicals which are dangerous to the health. Benzene, chloroform, carbon tetrachloride and carbon disulfide are among these chemicals, based on data by the International Agency for Research on Cancer (IARC). The laboratory manual entitled Chemistry is given special recognition as it requires no carcinogenic chemicals.

D. Carter and Fernando indicated that not all toxic chemicals are organic solvents. They point out the metals beryllium, cadmium, lead and mercury are considered severe industrial hazards. Their results are confirmed by NIOSH and CPSC.

The Chemical and Engineering News (C & EN), 1982 pointed out the results of a survey which indicates high school chemistry teachers order too many suspected or known carcinogens each year. The reason for this result, C & EN surmises, is the lack of instructor awareness for chronic health effects caused by chemicals.

Brubaker's survey indicates that most academic labs have no safety training program. In an earlier issue of C & EN (1981), it was stated that some educators believe a formal safety course will be mandatory in the chemistry

curriculum. Nicholls describes her safety course already implemented at the University of Illinois at Chicago Circle which includes identifying and handling toxic substances.

Once a teacher learns about safety, Mohrig asks how does one know if an experiement is a health danger. By monitoring the air is the only sure way. Several methods of monitoring were discussed by Freifeld who also mentioned the National Academy of Science recommendation to monitor air when organic substances are used three or more times per week. Pierce and senior students, McDonald and Scrogin, monitored the air during an organic experiment and found no overexposure to toxic vapors. All monitoring units discussed were an apparatus involving a gas chromatogram.

The level of toxic chemicals in the atmosphere can be controlled. Bayer concluded the levels of toxicity in the air depend on the rate of introduction and the rate of removal. New laboratory devices and adequate ventilation must be installed in facilities handling carcinogens according to C & EN (1978).

If an instructor uses a toxic chemical within the limits of exposure or chooses to remove these chemicals from the classroom, Joyce states a hazardous chemical disposal plan which is environmentally safe and conforms to federal, state and local regulations must be followed.

Chemistry teachers are considered hazardous waste generators, as pointed out by Allen who also warns failure to comply with the Environmental Protection Agency (EPA) regulations for proper and safe chemical waste disposal is open for prosecution. Sink disposal and ground burial are in violation of the EPA regulations.

The proper legal procedures for waste disposal were summarized by Young. He gave the teacher three simple choices: (1) hire the EPA, who charges a high fee to dispose of the waste; (2) classify waste as hazardous and non-hazardous, place in EPA approved containers and then hire this agency to dispose of the waste at a lower fee; or (3) recycle hazardous waste, reduce the volume used per experiment, and substitute chemicals of less toxicity. Young claims the latter to be the most practical choice. Rothchild stated 1,1 trichloroethane, when substituted for benzene, produced some unwanted side reactions. Therefore, a substitute chemical must not only have a lower risk value, but also no side reactions to the experimental results.

The regulations for hazardous waste disposal may vary among state and local governments. An instructor should check with local officials before initiating a disposal plan. In Indiana, any person dumping or delivering any hazardous waste to an unapproved dumping site can be fined up to $25,000 per day of violation. Iowa's local schools

work closely with fire marshalls, the EPA and the Department of Environmental Quality to remove dangerous chemicals from the classroom (C & EN, Sept., 1982). The Pennsylvania Department of Education provides a booklet for the proper disposal and storage of chemicals along with many other safety guidelines for any science laboratory upon request.

For a chemical not addressed or identified by this study, Gallagher of the American Chemical Society provides an address and phone number as a source of information pertaining to the handling and disposal of hazardous substances. Other resource books for handling hazardous chemicals include The Firefighter's Handbook of Hazardous Materials and CRC Handbook of Laboratory Safety.

Finally, Johnson and Walters both implemented the same Lawrence Livermore Laboratory's safety program which can easily be applied to an academic laboratory. This program provides safety guidelines for handling the chemical carcinogens and toxic substances and it is recommended because of its inventory requirements and detailed labeling system.

CONCLUSION

What chemicals are hazardous?

The literature clearly establishes the need for teachers to be informed of the chemicals which are potential

health hazards. Although there is no research data to prove a definite quantity or concentration of a substance as the sole cause for toxic effects on humans, the International Agency for Research on Cancer (IARC) and NIOSH both agree benzene is a known carcinogen while chloroform and carbon tetrachloride are probable carcinogens. Formaldehyde is an animal carcinogen and mutagen. Carbon disulfide is thought to have many bodily effects and has been classified as an explosive.

How can the hazard be reduced?

Educating the laboratory instructors to the hazards of certain chemicals is the initial approach to reducing the dangers of chronic poisons in the classroom. Local universities should provide a health safety course for this purpose. NIOSH already has regional safety training programs for industrial workers. Other means of reducing the hazards are using a less hazardous chemical as a substitute, reduce the volume of toxic chemicals used in an exercise, use adequate ventilation and monitor the laboratory atmosphere. The only sure way to know if an experiment is operating within the limits of exposure, is to monitor the air. Most monitoring systems are too expensive for school corporations to purchase. A local industry could possibly be contacted for this service.

What are handling and disposal procedures?

The EPA, state and local agencies each have regulations for the proper disposal of hazardous chemicals. In order to dump a hazardous substance in the drain or ground, one must acquire a permit. Failure to comply with federal requlations can mean prosecution and a costly fine.

The EPA does chargé for disposal of waste in their approved landfills. To reduce this cost, a chemistry teacher can clssify all waste as either hazardous or non-hazardous and label the contents of each container. To reduce the quantity of waste, the instructor should recycle hazardous chemicals, reduce the volume used in an exercise, and substitute less toxic chemicals.

RECOMMENDATIONS

It is recommended that:

1. Laboratory instructors participate in a formal health safety program and inform students of the potential health hazards involved in an exercise.
2. All carcinogenic chemicals be removed from the classroom and storage areas, never to be used again.
3. A predetermined waste disposal program be formulated and used before an experiment is performed.
4. If the benefit from using a toxic chemical outweighs its risk, the instructor must adhere to proper ventilation, recycling of waste and volume reduction.

APPENDIX

HEALTH and SAFETY TABLES

APPENDIX

Table 1

Registry of Toxic Effects of Chemical Substances, 1984

CHEMICAL	OSHA* LIMITS	NIOSH* LIMITS	BODILY EFFECTS
Acetone	2,400 mg/m^3	590 mg/m^3	Irritation to liver, kidneys, nervous system
Benzene	50 ppm/10 min.	1 ppm/60 min.	Leukemia
Carbon disulfide	20 ppm/8 hrs.	10 ppm/15 min.	nervous system reproductive systems, heart
Carbon Tetrachloride	25 ppm/8 hrs.	2 ppm/60 min.	liver cancer
Chloroform	50 ppm	2 ppm/60 min.	central nervous system, liver or kidney tumors
Ethylene dichloride	-----	2 ppm/15 min.	cancer
Formaldehyde	10 ppm/30 min.	1.2 mg/m^3/30 min.	irritation of the lungs
Methanol	200 ppm	800 ppm/15 min.	blindness
n-Hexane	----	350 mg/m^3	---------
Toluene	500 ppm/10 min.	20 ppm/110 min.	nervous system
METALS			
Beryllium	----	0.5 mg/m^3/130 min.	lung cancer
Cadmium	----	200 mg/m^3/15 min.	lung and kidney effects
Mercury	0.1 mg/m^3/8 hrs.	0.05 mg/m^3/8 hrs.	central nervous system and mental effects

*The limits of exposure are for an eight hour day unless otherwise stated.

NOTE: This is a partial list of toxic chemicals; more than 100,000 chemicals have been investigated.

Table 2

Selected Laboratory Manuals and Their Toxic Chemicals

TITLE	COPY RIGHT	TOXIC CHEMICALS	
		SEVERE	MODERATE
Chemistry: Experimental Foundations	1975	Benzene and Formaldehyde	Toluene and Methanol
Chemistry: An Investigative Approach	1976	Benzene, carbon disulfide, carbon tetrachloride, and formaldehyde	Acetone, methanol, toluene, and n-Hexane
Chemistry Today Lab Manual	1976	Benzene, carbon tetrachloride, chloroform, and formaldehyde	Acetone and methanol
Exercises and Experiments in Chemistry	1978	Benzene, carbon disulfide, carbon tetrachloride and formaldehyde	Acetone and methanol
Laboratory Chemistry	1979	Carbon disulfide, carbon tetrachloride and ethylene dichloride	Acetone and methanol
Chemistry	1980	None	Acetone, methanol, n-Hexane, trichloroethane and toluene

Table 3

Council of State Science Supervisors'
List of Hazardous Chemicals

EXPLOSIVES	KNOWN CARCINOGENS*	PROBABLE CARCINOGENS*
Benzoyl Peroxide	Arsenic Powder	Acrylonitrite
Carbon Disulfide[1]	Arsenic Pentoxide	Cadmium Powder
Diisopropyl Ether[2]	Arsenic Trichloride	Cadmium Chloride
Ethyl Ether[2]	Arsenic Trioxide	Cadmium Sulfate
Picric Acid	Asbestos	Carbon Tetrachloride
Perchloric Acid	Benzene	Chloroform
Potassium Metal[2]	Benzidine	Ethylene Oxide
	Chromium Powder	Nickel Powder
	Chromium (VI) Oxide	o-Toluidine
	Lead Arsenic	
	Sodium Arsenate	
	Sodium Arsenite	

[1] Vapor in the air can be explosive.

[2] Dangerous upon aging and explosive upon contact with air.

*Based on the International Agency for Research on Cancer (IARC) classification.

Table 4

Council of State Science Supervisors' List of Known Animal Carcinogens* or Mutagens**

	Animal Carcinogens	Mutagens
Acetamide	X	X
Ammonium Chromate		X
Ammonium Dichromate		X
Aniline	X	
Antimony Oxide		X
Beryllium Carbonate	X	X
Ehtylene Dichloride	X	X
Formaldehyde	X	X
Indigo Carmine		X
Potassium Chromate		X
Potassium Permanganate		X
Silver Nitrate		X
Sodium Nitrate		X
Toluene		X

*Based on the International Agency for Research on Cancer (IARC)

**Based on the Registry of Toxic Effects of Chemical Substances

NOTE: This is a partial list of chemicals with substantial evidence of carcinogenicity. A comprehensive list can be obtained from NIOSH. Further, each substance listed here may have additional health hazards.

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